Aircraft Type and Registration:	Raytheon 390 Premier 1, N200PR
No & Type of Engines:	2 Williams FJ-44 turbo-jet engines
Year of Manufacture:	2001
Date & Time (UTC):	7 April 2004 at 0932 hrs
Location:	Blackbushe Airfield, Hampshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	FAA Private Pilot's Licence with Instrument Rating
Commander's Age:	39 years
Commander's Flying Experience:	4,511 hours (of which 413 were on type) Last 90 days - 60 hours Last 28 days - 12 hours
Information Source:	AAIB Field Investigation

Synopsis

After takeoff the pilot was unable to raise the landing gear and was presented with failure indications affecting both the lift dump and anti skid systems. Following a successful landing at Farnborough, and discussions with the aircraft's maintenance organisation, the aircraft was flown to Blackbushe for further technical investigation. After landing on Runway 26 the aircraft left the runway, struck a series of obstructions and was destroyed: there was no fire and the pilot was uninjured.

The support bracket for the right main landing gear weight-on-wheels switch was found to have sustained a pre-impact failure which accounted for the indications reported by the pilot. Five recommendations have been made as a result of this investigation.

History of the flight

The following has been compiled from witness statements and evidence retrieved from the Cockpit Voice Recorder (CVR) and the Enhanced Ground Proximity Warning System (EGPWS).

It was planned that the aircraft should undertake a series of flights originating from Luton Airport, Bedfordshire. The first flight from Luton to Humberside Airport was uneventful, and the aircraft took off for the second flight from Humberside to Dublin with the pilot and six passengers on board. Once airborne the pilot selected the landing gear control handle to UP, but although the control handle moved the landing gear remained in the fully extended position with three green lights illuminated on the landing gear indicator. The pilot attempted to re-cycle the landing gear but without success; later he noticed that he also had indications of LIFT DUMP FAIL and ANTI SKID FAIL.

Since the aircraft had insufficient fuel to continue to Dublin with the landing gear extended the pilot decided to divert to Luton, where he knew engineers familiar with the aircraft would be available. After further consideration he subsequently diverted to Farnborough and arranged through ATC for ground engineers from the aircraft's maintenance organisation, who were located at the nearby Blackbushe Airfield, to meet the aircraft. Whilst en route to Farnborough the pilot consulted the checklist for LIFT DUMP FAIL and noted that with this system inoperative the landing distance required (LDR) was increased by 53%; the landing distance available (LDA) at Farnborough of 1,800 metres was greater than this increased LDR. He also thought that he had consulted the ANTI SKID FAIL checklist, but contrary to this checklist Flap 30° was used for landing and the anti skid switch was left in the ON position. Conscious of the increased LDR he requested permission to land short of the displaced threshold on Runway 24 at Farnborough. After touchdown the pilot attempted to deploy the lift dump system but, as expected, the lift dump spoilers failed to extend. Nevertheless, the landing roll was uneventful and, in particular, the braking seemed effective; at one stage, and despite the ANTI SKID FAIL indication, the pilot thought that he felt the anti skid system operate.

The aircraft taxied to the parking area and was met by an engineer from the aircraft's maintenance organisation. After discussions with the pilot the engineer carried out a visual inspection of the landing gear weight-on-wheels (WOW) switches and utilised the built in test equipment to conduct checks of the spoiler control system and the anti skid system. There were no obvious problems with the WOW switches and neither system test revealed any fault but the engineer, aware of a history of lift dump system problems with the aircraft type, suggested that the aircraft should be ferried to Blackbushe for further technical investigation. The pilot arranged for his passengers to travel to their intended destination by alternative means and then verified that sufficient landing distance was available at Blackbushe, including an allowance for the continuing failure of the lift dump system.

(In the prevailing conditions this calculated LDR was almost exactly the same as the LDA.) The pilot then agreed to fly to Blackbushe and decided to complete the short flight without attempting to retract the landing gear.

The takeoff from Farnborough was uneventful, but shortly after becoming airborne the pilot noticed a recurrence of the LIFT DUMP FAIL indication. Since this had been expected, and allowed for, the pilot continued to Blackbushe but decided not to attempt to deploy the lift dump system after landing. Having consulted the abnormal checklist for LIFT DUMP FAIL on the previous flight the pilot did not attempt to refer again to that checklist. The pilot could not recall seeing the ANTI SKID FAIL indication during the flight to Blackbushe.

The meteorological conditions at Blackbushe were good with a surface wind of 350°/10-15 kt and no significant weather. The pilot joined downwind for a visual approach and landing on Runway 26 and the touchdown, which was witnessed by several people on the ground, appeared to be about 100 metres beyond the displaced threshold. After touchdown the pilot applied the brakes progressively but felt no retardation; he released and then reapplied the brakes but was still unaware of any discernible braking effect. Conscious of the poor overrun for Runway 26 the pilot decided to initiate a takeoff and applied power, but the engine response felt slow and he decided that there was now insufficient runway remaining to achieve rotation speed. The take-off configuration warning horn was recorded by the CVR and indicated that the thrust levers were forward of the 80% position for 3.7 seconds. Having now decided to abandon the attempt to take off the pilot closed the thrust levers and reapplied the brakes, but once again perceived no effective braking. The end of the runway was now rapidly approaching and he decided to steer the aircraft off the paved surface and on to the adjacent grass in an attempt to increase the retardation. After travelling across the grass for a short distance the aircraft yawed to the left, but continued in the same direction whilst skidding sideways and crossed a parallel taxiway before hitting a small embankment. The aircraft eventually came to a halt pointing roughly in the opposite direction to travel and with the wings detached from the fuselage; there was no fire. The fuselage came to rest on its left side and the pilot, who was uninjured, was therefore unable to vacate the aircraft through the main access door which was situated on the left side of the aircraft. The emergency exit, however, located on the right of the fuselage had opened during the impact and the pilot made his way aft into the passenger cabin to make his escape. Upon reaching the exit he realised that one of the engines was still running and he returned to the cockpit to shut down the various aircraft systems before leaving via the emergency exit.

Pilot's Experience

The pilot started flying in the mid 1980's and after gaining sufficient flying hours he obtained a commercial pilot's licence. Since then his professional flying had been conducted predominantly on light twins and business jets, although he had flown the BAe 146 for two years with an airline. In recent years he had been flying a Cessna Citation for the owner of the accident aircraft, but in April 2002 the owner changed aircraft and bought a new Raytheon Premier 390 (manufacturer's designation RB 29). Type training was provided by a training organisation in the USA under contract to the manufacturer. The aircraft was registered in the USA and the pilot therefore needed to obtain a FAA flying licence. Since the aircraft was to be used only for private flights the pilot obtained a FAA PPL on the basis of his UK licence. At the time of the accident the pilot had accumulated 413 hours on type most of which had been on RB 29.

The pilot reported that, as expected, there had been a number of teething problems with the new type, but whereas these would normally be resolved as the aircraft matured, in the case of RB 29 the problems persisted. A number of these problems included the lift dump system but, in general, there seemed to be no common factor; however, many involved spurious indications. The owner grounded the aircraft for a period to allow the engineers time to address the problems and changed the maintenance organisation, but although these measures produced some improvement the aircraft continued to perform below the owner's expectations. In November 2003 the manufacturer agreed to replace RB 29 and a new aircraft, RB 79, was delivered. The pilot indicated that although RB 79's reliability was somewhat improved over that of RB 29, some problems remained. The pilot stated that the continuing difficulties with the aircraft's reliability had affected his confidence in the machine and, in particular, he lacked confidence in the authenticity of the aircraft's warning systems.

Accident Site

The aircraft had come to rest at the end of Runway 26, in the fuel bund[1]. Examination of the runway, at the point of touchdown estimated from witness evidence, did not reveal any tyre markings and therefore it was not possible to determine the exact point at which the aircraft had touched down. A later download of the EGPWS revealed the point at which the aircraft had passed through 50 feet on the approach, and from this and data provided by the manufacturer, the estimated touchdown position was derived, this is shown on Figure 1. Some 580 metres from the threshold of Runway 26, tyre markings were evident which were continuous and followed a path that met an area of ground marks on the grass to the left of the runway. These were grey in appearance with the tyre tread pattern also visible. The initial marks were of two lines, one to the left and the other to the right of

[1] Bund. An embankment constructed to protect the fuel storage area

the runway centre line, with the distance between them matching that of the distance between the left and right main wheels of N200PR. These marks followed the centre line of the runway for around 180 metres, after which they deviated toward the left. At this point the nose wheel tyre markings became more prevalent. During this left turn, the left tyre mark was wider than the mark deposited by the right tyre, indicative of the crosswind lifting the right wing. The markings showed the aircraft had left the runway surface to the left and entered soft ground and then followed a track of 224°. Some 170 metres after leaving the runway the nose wheel marks crossed with the left wheel ground marks, indicating a progressive yaw to the left with the aircraft maintaining the same track. A short distance later the aircraft passed over the taxiway at the end of Runway 26, leaving black marks from the main landing gear tyres and no mark from the nose, indicating that the nose gear left the ground at this point. The aircraft had now yawed to the left through 90° and the right wing was pointing in the direction of travel. The nose gear then fractured, following which the right wing contacted the banking of the fuel bund; the right forward section of the fuselage then contacted a tree. Figure 1 shows the path of the aircraft during the accident.

When the wing was abruptly stopped by the fuel bund, the aircraft rolled and pivoted about the tree to the right, in the process detaching the entire wing due to the fracture of the wing to fuselage attaching tie rods. When the aircraft finally came to rest the wing had become airborne and landed on top of the fuselage, just aft of the cockpit area. In the final accident sequence the right main gear had also collapsed and the right engine had detached from its pylon, but was retained to the aircraft by fuel and control lines.

The aircraft had come to rest with the fuselage lying on its left side, thus preventing easy access through the main door. Fortunately, the emergency exit was located on the right of the aircraft and the pilot was able to egress through it. The emergency exit door was found lying in the aircraft on the left passenger seat directly opposite the door and in a position indicating that it had fallen into this position after the aircraft came to rest.

There was no fire, but the right wing fuel tank had been ruptured and had leaked a significant amount of fuel before it was staunched by the fire service. The aircraft had come to rest within a few metres of entering the fuel storage area, which contained three fuel trucks full of aviation gasoline and several propane cylinders; this was all within a few metres of the busy A30 trunk road.

Aircraft Description

General

N200PR was a light business jet powered by two turbojet engines. The monocoque fuselage of the aircraft was made of composite material, with the wing constructed of metal. The interface between the wing and the fuselage was by the use of four metal tie rods and a shear attachment fitting at the front of the wing centre section. Access to the aircraft was through a main access door located on the left of the fuselage, with an emergency exit on the right side of the aircraft. The aircraft had been certified by the FAA under Regulation 14 CFR Part 23, which allowed the aircraft to be operated by a single pilot under instrument flight rules.

Weight On Wheels (WOW) Switches

To provide an indication of whether the aircraft was in the air (IN AIR) or on the ground (ON GND), WOW switches were installed on each of the main landing gear torsion links: their operation is depicted in Figure 2. Each switch consisted of a plunger that operated four internal microswitches. The WOW switch was mounted on the upper torsion link and the target used to depress the plunger was installed on the lower torsion link of each main landing gear. When the aircraft was ON GND the landing gear strut would be compressed, opening the torsion links and moving the target away from the plunger of the WOW switch. In this condition the microswitches would be open indicating to the various systems that the aircraft was ON GND.

Once the aircraft was in the air the gear strut would extend and the torsion links expand, allowing the target to depress the plunger of the WOW switch and close the microswitches. Therefore, to provide an IN AIR indication to the various systems, the microswitches are closed.

The adjustment (rigging) of the WOW switch, so that the target correctly contacted the plunger IN AIR, was accomplished by lower and upper adjustment nuts which had to be tightened and loosened in unison to prevent undue stress on the WOW switch and bracket (Figure 4). Once adjusted the nuts would be wire locked together.

Landing Gear Retraction

The tricycle landing gear was retracted by the operation of the cockpit landing gear lever. When the aircraft was on the ground a locking solenoid prevented the lever from being moved to UP. Once the aircraft was in the air, the left WOW switch commanded the locking solenoid to de-energise allowing the handle to move freely.

Upon selecting the landing gear control handle to UP the first action was for the inboard landing gear doors to open. However, for this to occur the right WOW switch must indicate IN AIR; this prevents the operation of the door retraction circuit on the ground. Once the doors had opened the landing gear selector valve would port hydraulic pressure to the retract actuators of the three landing gears. After the gears had retracted, the inboard doors would then return to their faired position.

The warning system provided an indication of the gears being down and locked by the use of three green light indicators, located beside the gear selector lever. Red gear transition lights provided an indication that the gears were not in the commanded position.

Lift Dump System (Figure 3)

N200PR was equipped with six spoiler panels, three on each wing. The two outboard spoiler panels on each wing provided the speedbrake function as well as roll augmentation. The inner spoiler panel on each wing, in combination with the two outer spoiler panels, accomplished lift dump. A spoiler control unit (SCU) electronically controlled the speedbrake/lift dump function with the panels being hydraulically actuated.

Speedbrake operation only occurred if certain aircraft configurations were met: these being either left or right WOW switch indicating IN AIR, both engine thrust levers advanced beyond 80% N1 and the flaps at a position less than 23°. The speedbrakes would then operate as commanded by the speedbrake switch located on the centre pedestal.

Lift dump is utilised to rapidly reduce the lift during landing thereby assisting the aircraft to stop. On N200PR, lift dump was provided by the use of a manual lever located to the rear of the centre pedestal. Prior to touchdown, the system is 'armed' by moving a LOCK/UNLOCK switch to UNLOCK. This removes a solenoid lock on the manual lift dump lever allowing it to move freely. On landing the lift dump handle is then moved aft to EXTEND, the spoiler panels are then deployed. No other conditions are required to be met: it is therefore possible to operate the lift dump system in the air.

The SCU monitors the system to detect any malfunctions. Incorporated in this monitor function is a built in test (BIT) which is carried out prior to each flight after the aircraft electrical and hydraulic systems has been powered. This BIT checks the entire system and, if it is successful, allows the system to operate. Any failure during this test renders the system inoperative with an associated warning on the cockpit warning display. Included in this test is the WOW switch status. For the BIT to operate the aircraft had to be on the ground with ON GND indications from both the left and right WOW switches.

The SCU continues to monitor for faults throughout the flight, if a fault is detected it provides a warning in the cockpit and renders that system inoperative. Faults can only be reset once the aircraft is on the ground and the BIT test have been completed. One such monitor is for a WOW disagree: if a discrepancy between the left and right WOW switches persists for more than six seconds then the SCU will fail the lift dump system. The LIFT DUMP FAIL light will illuminate on the cockpit warning panel and the system will be rendered inoperative, although the speedbrake function will remain. Any attempt to operate the lift dump with LIFT DUMP FAIL annunciated would result in a warning light in the lift dump handle and an aural warning tone in the cockpit.

Braking and Anti Skid System

The aircraft was equipped with multi-disc, hydraulically operated brakes on the left and right main wheel assemblies. Operation of the brakes is through the pilot's rudder pedals connected via cables to the power brake/anti skid control valve (PBCV). The PBCV converts the input from the cables to a related hydraulic pressure, which is then applied to the hydraulic actuators on the brake discs. Feedback of brake application, to provide 'feel' to the pilot, is effected by springs on the input to the PBCV.

In addition to the normal braking above, the aircraft was equipped with an anti skid system. This is commanded by an anti skid control unit (ASCU), and powered when the anti skid switch, in the cockpit, is selected to NORM. During normal operation of the anti skid system the ASCU receives inputs from the left and right WOW switches together with wheel speed transducers on each of the main wheels. The WOW switches indicate to the ASCU that the aircraft is on the ground; this is for touchdown protection and prevents the application of brakes prior to landing. Once the WOW switches indicate ON GND, the system will wait for three seconds before allowing the brakes to apply, or until the wheel speed had reached a speed above 60 kt.

The anti skid operation will commence once the brakes have been applied and the wheel speed has increased to above 60 kt. The system will then monitor the wheel speed and determine the optimum brake application by modulating the hydraulic pressure output from the PBCV. This requires the system to determine a reference skid speed; thus initially the brakes continue to apply pressure until the tyres start to skid. Once a skid had been detected, the ASCU releases the brake pressure to prevent a sustained skid. Following this initialisation, the ASCU will then regulate the brake pressure through the PBCV and modulate it to provide the optimum level for stopping the aircraft without inducing a skid. If the brakes were released and then reapplied, the system would have to repeat this initialising sequence.

For effective braking there is a need for positive contact between the tyre and the paved surface; this relies on a vertical load which, on this aircraft, is augmented by the operation of lift dump. When the aircraft ground speed reduces the vertical load increases and the brakes become more efficient. This provides a non-linear trend to the aircraft's ground speed when it is slowed by the brakes, with the greatest amount of speed being removed during the final stages of the landing roll.

Take-off Configuration Warning

To prevent the aircraft taking off in an abnormal configuration it was equipped with a system which provided an aural warning which sounded if a take off was attempted with any of the following conditions:

- Both roll/speedbrake surfaces greater than 1°
- Either speedbrake/lift dump lever sensors in the extended range
- Either lift dump surface not retracted
- Flap position greater than 22°
- Flap fail signal
- Pitch trim actuator between 3.18° and 4.39°

The system assumed that a takeoff was being attempted if either left or right thrust lever was advanced beyond 80%.

Detailed Wreckage Examination

The aircraft wreckage was taken to the AAIB facility at Farnborough for further investigation. Examination of the wreckage revealed that the landing gear was in the extended position, the flaps were fully extended and all speedbrake panels were retracted. The main landing gear tyres were fully inflated with the tread still visible and there were no flat spots or signs of aquaplaning. The nose wheel had been thrown clear of the wreckage and was found beyond the fuel depot, it had deflated but otherwise had little damage. The main wheels were free to turn and the brake pads were intact with the brake wear indicators showing little brake disc wear, there were no signs of overheating in this area.

Inside the cockpit: the manual lift dump handle was in the RETRACT position and the lock/unlock switch in LOCK, the speedbrake switch was in the RETRACT position and the anti skid switch was in NORM. The left engine throttle was in CUTOFF and free to move and the right engine throttle was stuck in IDLE.

Because the pilot had reported that he had been unable to retract the main landing gear the WOW switches were examined in detail. Checks of the electrical operation and the rigging of the switches found them to be correct. However, the right main landing gear WOW support bracket was found fractured and the fracture surface was not as expected for an overload failure associated with impact forces. The fracture was perpendicular to the landing gear torsion link it was fitted to, and ran across the bracket from a hole used to retain the tang of a washer (see Figure 4). The bracket was sent for metallurgic examination, along with the intact support bracket for the left gear WOW switch.

Metallurgy

The metallurgic examination revealed that the right WOW support bracket had cracked due to stress corrosion which had initiated at the tang washer outer tang support hole (see Figure 4). Localised galvanic corrosion had been set up at the outer tang support hole due to the presence of the dissimilar metals of the aluminium support bracket and the steel tang washer, and brought about by contact with an electrically conductive liquid such as rain water. The stress part of the mechanism was due to the tang washer having been rotated in relation to the WOW switch, causing the inner tang of the washer to become jammed in the threads of the WOW switch. This caused the outer tang of the washer to be forced against the edge of the outer tang support hole, causing the edge of the outer tang to penetrate the paint protection and apply a tensile stress on the bracket. In addition, corrosion was also discovered on the underside of the bracket where the teeth of the steel lock washer had 'bitten' through the paint and into the aluminium of the bracket; this had also set up galvanic corrosion.

The left WOW support bracket was also examined, this revealed that its tang washer had similarly rotated in relation to the WOW switch. A microscopic examination of the outer tang support hole also revealed the beginnings of stress corrosion cracking.

Component Testing

Both WOW switches were tested in-situ and were found to operate normally. The load required to operate each microswitch, via the plunger, was within the manufacturers specified limits.

The ASCU, PBCV and the wheel speed transducers were tested by the manufacturer. All of the units tested to the specification defined for the units and did not reveal any other defects.

The SCU was taken to the manufacturer for a detailed examination, including the download of its fault memory. The SCU was tested and found to conform to the required specification. The information contained in the download can be found in Appendix A. Two sets of 'NM' codes were recorded which indicate faulty WOW switches, and these occurred concurrently indicating that a BIT test and reset must have been carried out between them. It has been determined that the first set of codes related to the LIFT DUMP FAIL shortly after takeoff from Humberside. It is known that the engineer carried out a BIT test and reset of the controller at Farnborough, and therefore the second set of NM codes can be related to the flight from Farnborough to Blackbushe.

Emergency Exit Door

The emergency exit door on the aircraft was located on the right of the main fuselage. It had a plug type door which opened inwards into the aircraft cabin. Locating lugs at the bottom of the door met with pads in the lower doorframe, when it was inserted into the door aperture. Two latches at the top of the door located onto pads in the upper door aperture. Release of the door involved the pulling of a handle which retracted the latches away from the upper pads and allowed the door to pivot about the lower door pads, before being pulled upwards out of the aperture. Door adjustment, to allow a flush fitting of the door, was carried out by shimming the upper locating pads.

The emergency exit door was inspected for any signs of damage to explain why it fell inwards during the accident. The door was intact and the upper latches operated normally when the emergency exit handle was pulled, with the latches returning to their retaining position when they were released. The door was installed back into the door aperture, once installed it was obvious that the door no longer fitted the aperture snugly. There was a clear gap at the top of the door and the door was not faired to the aircraft fuselage. Also the upper locating latches were no longer aligned with the locating pads.

Examination of the structure showed that the composite structure above and forward of the door had been significantly damaged during the accident. This had caused the structure to deform and weaken to the extent that the upper locating latches no longer aligned with the locating pads.

Flight Time and Hobbs Meter

The aircraft was equipped with a "Hobbs" meter, which recorded the actual flight time. The meter was configured to start recording once the right WOW switch indicated IN AIR and then stop when the switch indicated ON GND. The last confirmed Hobbs meter reading was recorded during N200PR's last maintenance input on 2 April 2004, with a reading of 101.2 Hours.

Based on the aircraft trip log and CVR flight times it was estimated that the aircraft had flown 3.07 hours since the 2 April 2004. This would give an expected Hobbs meter reading of 104.27 Hours. The actual reading on the meter, following the accident, was 103.3 Hours, a difference of 0.97 hours or 58 minutes. This equates to the approximate flight time from Humberside to Farnborough and onward to Blackbushe and indicates a continuous failure of the right WOW switch after departure from Humberside.

Maintenance

When the aircraft arrived at Farnborough it was met by an engineer from the maintenance organisation based at Blackbushe. The engineer carried out several actions in an attempt to diagnose the problem. He checked the WOW switches on both main landing gears, by crawling under the wings and physically moving the wiring and checking the operation of the plungers. He did not feel that the switches were loose nor did he notice any problems with the switch operation. He then carried out BIT checks on the ASCU and the SCU, both of which were indicated serviceable systems. Following the BIT test on the spoiler control unit the LIFT DUMP FAIL warning also cleared.

Lift Dump System Modification

Due to a number of previous landing accidents implicating the lift dump system the FAA issued AD 2003-07-09 and AD 2003-10-05 which imposed restrictions on the aircraft landing performance. In response to these the aircraft manufacturer issued a Service Bulletin (SB) 27-3608, to modify the existing lift dump system. The FAA accepted the SB as a means of compliance with the FAA AD which then allowed the removal of the performance restrictions.

The original lift dump system was operated via the speedbrake switch; this was a manual operation which required the use of the switch at touchdown. For the lift dump to deploy it required either of the main landing gear WOW switches to indicate ON GND and the nose gear WOW switch to also indicate ON GND, as well as both engine throttles to be at IDLE. Once these conditions were met and when the speedbrake switch was placed in EXTEND it would electrically latch in this position and command the wing spoiler panels to deploy. Included within the SCU was a WOW switch disagree monitor, if the time between a main gear WOW switch indicating ON GND and the nose gear WOW switch indicating ON GND exceeded six seconds then a LIFT DUMP FAIL would occur, preventing deployment of the wing spoilers.

SB 27-3608 carried out several changes to this system. The WOW switch on the nose gear was removed and the design of the WOW switches on each of the main landing gears was changed from a rotary type switch to the plunger switch found on N200PR. In addition, a manual LIFT DUMP handle was installed at the rear of the centre pedestal. The system operation was then as described in the section above headed 'Aircraft Description'. The SB only required changes external to the SCU; all of the functions within the control unit remained, including the six second monitor for WOW disagree, but the monitor now looked for a discrepancy between each main landing gear WOW switch.

The installation of the SB was carried out based on kit drawings. These detailed the installation of the WOW switches and the LIFT DUMP handle. The WOW switch installation however omitted to provide details on the build up of the switch mounting hardware and as such omitted to show the location of the lock washer or tab washer. The WOW switches on N200PR had been installed with the tab washer between the upper nut and the bracket, and the lock washer between the lower nut and the bracket, which had led to damage of the support bracket. (See Figure 4.)

The aircraft manufacturer had completed the SB on N200PR in September 2003.

Aircraft Performance

The aircraft had been certified by the FAA in accordance with the performance criteria of Regulation 14 CFR Part 23. Performance data was presented in the FAA Approved Airplane Flight Manual (AFM) which provided the following information on the basis of the data:

> *All performance data presented in this manual is based on flight test and has been corrected for the following factors:*
>
> 1. *Engine thrust rating less installation losses, airbleed, and accessory loads.*
> 2. *Full temperature accountability with the operational limits certified.*
> 3. *Wind accountability per 14 CFR Part 23 provisions.*
> 4. *Humidity accountability per 14 CFR Part 23 provisions.*
> 5. *Take-off and landing performance based on smooth, dry, paved runways.*

It is significant that performance figures in the AFM are the figures achieved during flight test and they are not factored to allow for any operational variabilities; under the terms of 14 CFR Part 23 regulations such factoring is not required. The AFM also outlines the flight test conditions on which the published performance was based. Landing performance data was based on the following criteria:

> 1. *Thrust was set to establish a 3° approach with the airspeed stablized at V_{REF}.*
> 2. *Both thrust levers were moved to the idle position as the airplane passed 50 ft above the runway surface.*
> 3. *At touchdown, maximum braking was immediately initiated.*
> 4. *Lift dump spoilers were selected immediately after nose gear touchdown.*
> 5. *Maximum braking was maintained to a full stop.*

Landing performance charts for abnormal configurations/situations are generally not provided but ABNORMAL and EMERGENCY PROCEDURES contain increases to the normal landing distance. Thus, for example, the LIFT DUMP FAIL abnormal checklist states that landing distance will increase by approximately 53%. The manufacturer advises that since these increases are applied without taking into consideration ambient conditions or the aircraft weight they are deliberately conservative. Landing performance data for multiple failures and for wet or icy runways are not provided.

An example of the AFM landing performance chart is shown at Figure 5. The data are presented in a commonly used format, but they are of small scale and minor plotting errors can lead incrementally to significant miscalculations. The manufacturer recognised the limitations of the published charts, especially when used in the air during single-pilot operations, which is why abnormal and emergency checklists included percentage increases to normal landing distances on the presumption that pilots would have calculated their normal landing distance on the ground before departure. At the top left corner of the chart the conditions associated with the data published on the chart were listed, but the charts did not reflect all the landing performance criteria listed above. In particular the braking technique was omitted. Additionally, the pilot stated that his initial type training did not include all of the information on the actions necessary to achieve the published landing performance.

Following a series of runway overrun accidents involving non-deployment of the lift dump spoilers, the manufacturer designed a modification to the lift dump system. Pending installation of this modification the FAA issued AD2003-07-09 and AD2003-10-05; these required that no credit be taken for the improved landing performance provided by the lift dump system and all landings should be planned on the basis that the lift dump system was inoperative. Thus in March 2003 the manufacturer issued aircraft operators with a temporary change to AFMs which provided performance charts for a landing with the lift dump system inoperative (Figure 6): once the lift dump system had been modified this chart should then have been removed from the AFM. This temporary landing performance chart included lift dump spoiler status and braking technique in the list of associated conditions. The landing distances provided by this chart were significantly less than increasing the normal landing performance by 53%, which was used to represent the most conservative condition.

The aircraft involved in this accident had a modified lift dump system; however, the temporary landing performance chart for lift dump failure had not been removed from the AFM. When checking the required landing distance for Blackbushe Airport, whilst on the ground at Farnborough, the pilot had used this temporary chart.

Abnormal and Emergency Procedures

The AFM contains all emergency and abnormal procedures together with associated explanatory notes, warnings and cautions. An FAA approved abbreviated checklist is also published and is intended for quick reference in flight. The introduction to the abbreviated checklist warns that whilst the intent of all warnings are included, most explanatory items, notes and cautions are omitted for brevity.

a) The LIFT DUMP FAILURE (LIFT DUMP FAILURE ANNUNCIATOR ILLUMINATED) procedure, is identical in the AFM and the abbreviated checklist and is as follows:

1. Lift Dump .....Full or partial lift dump effectiveness is lost. Increase landing distance by 53%.

b) The lift dump fails to extend (lift dump warning tone sounds) procedure is to be followed in the event that that the lift dump fails to extend on landing and is as follows:

1. Brakes Apply and maintain maximum braking. (This procedure is printed in bold indicating that it is an 'immediate action' item.)

***WARNING**. Full or partial lift dump effectiveness is lost. Nearly continuous brake system releases may initially occur due to normal cycling of the anti skid system. Do not modulate the brakes. Maximum braking effort must be maintained until the airplane has stopped. Brake effectiveness will increase as the airplane decelerates.*

The immediate action is identical in the AFM and the abbreviated checklist; however, the associated **Warning** does not appear in the abbreviated checklist:

c) The ANTI SKID FAILURE (ANTI SKID FAIL ANNUNCIATOR ILLUMINATED) procedure in the AFM is as follows:

1. Anti Skid OFF

2 Landing FLAPS UP OR 10

3. Refer to FLAPS UP, 10, or 20 APPROACH AND LANDING procedure in this section.

4. Apply Brakes Steadily, Gradually Increasing Force to Avoid Skidding Tires.

***CAUTION.** Use of flaps 20 or DN for landing, with anti skid failed, is prohibited.*

***NOTE.** Landing distance will increase approximately : Flaps UP – 130%, Flaps 10 – 89%.*

This same procedure in the abbreviated checklist is almost identical but does not contain the ***Caution.*** The manufacturer advises that the restriction of landing with the flaps UP or at 10 is to improve the transfer of aircraft weight from the wing to the landing gear and thus reduce the possibility of skidding whilst there is little weight on the mainwheels.

Airport information

Runway 26/08 at Blackbushe Airport was 1,335 metres long with an asphalt surface. Both runways had displaced landing thresholds with Runway 26 having a declared LDA of 1,065 metres. At the time of landing the runway was predominantly dry with a few dark patches indicating damp areas and there were isolated, small puddles of standing water.

A partial assessment of the runway friction levels had been carried out the day before the accident. The assessment report indicated that the runway surface had less friction in the 26 direction and recommended that a full classification be conducted. The average friction value for the strips of runway 1.5 metres either side of the runway centreline (roughly the position of the mainwheels of the Premier when the aircraft is on the centreline) was 0.54. If this reading had been confirmed by the results of a full classification then that portion of the runway would normally require the runway to be promulgated by NOTAM as "liable to be slippery when wet". By comparison the overall friction level for the central portion of Runway 24 at Farnborough was 0.78, indicating the good friction properties of the recently laid porous friction course.

Tests and research

As a result of this accident together with other landing accidents and incidents the manufacturer has introduced a Supplemental Pilot Familiarization programme for existing owners to be conducted on the aircraft and designed to "ensure that you (owners) are familiar with both the aircraft systems and proper procedures necessary to deal with ….landing during adverse conditions". As part of this investigation a pilot from the AAIB participated in this training programme and flew with one of the manufacturer's demonstration pilots.

The programme includes a period of ground discussions covering swept-wing jet flying characteristics, an overview of previous landing accidents and a refresher on performance calculations. The training programme culminates with a two to three hour flight during which the owner is given the opportunity to practise a full stall and various landings, including use of the emergency brakes. Included in these landings are a max effort full stop landing with all systems operating and a final landing with a simulated lift dump system failure.

For the purposes of the AAIB flight the aircraft weight was adjusted to replicate that of the accident aircraft as closely as possible. However, with two pilots on board and the demonstration aircraft's higher basic weight the final landing was conducted about 500 pounds above the accident aircraft's landing weight. The AAIB pilot made the following observations during the flight:

'The brake system is cable operated with little effective feedback to the pilot of how much brake is being applied. It therefore takes some practice to achieve smooth braking during taxiing and, when applying maximum braking on landing, a conscious effort is required to ensure that the brake pedals are at full forward travel. During the max-effort landing with all systems operating normally retardation was impressive almost immediately the brakes were applied. Probably as a result, anti skid brake release was very noticeable.

During this flight the performance calculations for the landing with a simulated lift dump failure indicated an excess of about 1,000 feet of LDA over the LDR. The landing was made in accordance with the AFM technique outlined above with touchdown just beyond the landing threshold at a calculated speed of 114 kts. Maximum braking applied after touchdown achieved little or no discernible deceleration, and the pilot likened the feeling to that of landing on an icy runway. Unlike the max-effort landing with all systems operating the anti skid operation was not noticeable during the initial stages of the landing roll. Retardation was hardly noticeable and the end of the runway appeared to be approaching rapidly. However, as the speed reduced to about 80 kts the retardation increased dramatically and the aircraft came to a halt well within the calculated landing distance.

During flight the times for an engine acceleration were measured. The results indicated that the engines accelerate from flight idle to full power in about 4.5 seconds.

Subsequent to this accident the manufacturer issued Safety Comminque No 246, Landing Performance Awareness. Of particular relevance to this accident is the following extract covering the pilot's perception of braking efficiency:

For a maximum performance landing as stated in the AFM…….During the first ⅓ of the braking distance, the airplane speed will be reduced by approximately 8% of the touchdown speed. The pilot may perceive that this deceleration is not adequate, and that the projected stopping distance exceeds the available landing distance……As the airplane enters the middle ⅓ of the braking distance, the deceleration rate increases, resulting in a speed reduction to about 59% of the touchdown speed. The perceived stopping distance, although shorter now, may still appear to be in excess of the available runway. It will not be until the final ⅓ of the braking distance that the deceleration rate will increase to a level where a pilot will clearly perceive that the stopping distance is within the available runway length.

In the same Communique the manufacturer made known its intent to publish landing data for wet and contaminated runways.

Other accidents/incidents

The following is a list of worldwide reported accidents/incidents that have affected the Raytheon Premier 1 and that have similar circumstances to those of N200PR. In most cases, these are still under investigation and therefore, so that these investigations are not prejudiced in anyway, the information provided is based on limited factual evidence.

Las Vegas, Nevada, USA on 27 May 2004

After landing at Las Vegas airport, the aircraft overran the end of the Runway 07. The recorded surface wind four minutes prior to the accident was 160° at 15 kt gusting 20 kt. There were no faults reported on the lift dump system prior to approach, but it did not deploy during the landing roll. The aircraft was equipped with the pre SB 27-3608 lift dump system. This accident is still under investigation by the National Transportation Safety Board of the USA.

Sao Paulo, Brazil on 14 March 2004

The aircraft landed at Sao Paulo airport in heavy rain, with about 0.10" of standing water on the runway. After landing the lift dump was deployed successfully and the brakes were applied, but this did not seem to slow the aircraft. The emergency brake was then used which caused the aircraft to hydroplane off the end of the runway. This accident is currently under investigation by the Brazilian Departamento de Aviacao Civil.

Cannes, France on 20 Feb 2004

After landing at Cannes, France the aircraft overran the end of Runway 35. The aircraft was fitted with the post SB 27-3608 lift dump system, similar to N200PR. The wind at the time was 090° at 15-17 kt gusting 22 kt. After touchdown, the lift dump system did not deploy and the braking appeared ineffective. This accident is currently under investigation by the Bureau d'Enquetes et d'Analyses (BEA) of France.

Reno, Nevada, USA – 13 November 2003

Following the landing, the brakes appeared to have failed. The emergency brake was used which locked the main wheels and burst the tyres. During the flight, the pilot had received several warnings including LIFT DUMP FAIL and ANTI SKID FAIL. The wheels and brakes were subsequently replaced and the aircraft was then taken for a test flight during which the aircraft exhibited the same problems, including an inability to retract the landing gear. The pilot diverted to

Van Nuys, California where it was discovered that there was a mechanical defect with the rotary WOW switch. This aircraft had the pre SB 27-3608 lift dump system installed.

Windham, CT, USA on 17 April 2003

After landing the lift dump system failed to deploy. Emergency braking was then used to stop aircraft and it came to rest 300 feet before the end of the runway. The damage to the aircraft was limited to left gear, which had departed the runway hard surface. This aircraft had the pre SB 27-3608 lift dump system installed

Santo Domingo, Dominican Republic on 7 Jan 2003

Following the landing the aircraft overran the end of Runway 19 at Herrera Airport and came to rest in a car park. During the landing, the lift dump system failed to deploy and the LIFT DUMP FAIL light had illuminated. This aircraft had the pre SB 27-3608 lift dump system installed. The accident is currently under investigation by the Direccion General De Aeronautica Civil of Santo Domingo.

Norwood Memorial, MA, USA on 18 August 2002

On landing at Runway 28, with flap 10 selected, several attempts were made to deploy the lift dump and in each case the switch failed to 'latch' in position and the lift dump panels did not deploy. The pilot also felt that the braking was ineffective. The aircraft was then intentionally steered off the runway to the left, which then resulted in minor damage. This aircraft had the pre SB 27-3608 lift dump system installed.

Analysis

Survivability

Following the accident the aircraft had rolled onto its left side, possibly making it difficult to open the main access door. Fortunately, for the uninjured pilot, the emergency exit door, on the right side, had fallen into the aircraft and enabled his escape. However, as the door had fallen inwards during the accident, if passengers had been seated in the rows adjacent to the door, they may have been injured when the door fell inwards. The reason for the door falling in was due to distortion of the composite airframe during the accident sequence. This had allowed the upper latches of the door to become misaligned to the upper locating pads. With this lack of support of the upper part of the door it had fallen inwards and pivoted about the lower lugs before finally falling into the aircraft. There was no indication of any mis-rigging or defects with the emergency exit door.

Despite the distortion to the fuselage, the living space of the aircraft had not been compromised showing the relative strength of the composite structure. The metal wings had detached from the fuselage, not at the metal to composite interface but due to tensile bending failures in the mid point of the attaching rods. All of which were attributed to the abrupt halt of the right wing and subsequent rolling of the fuselage during the final stages of the accident.

Fortunately there was no fire; but had there been a post impact fire then the proximity of the aircraft to the fuel storage area and the main trunk road, in addition to the composite structure could have resulted in a much more significant event.

Engineering Issues

WOW switch Failure

After takeoff from Humberside the pilot was unable to raise the landing gear despite normal movement of the landing gear lever. This suggested a failure of the right WOW switch, providing a continuous ON GND indication, whilst the aircraft was in the air. A similar failure of the left WOW switch would have restricted movement of the cockpit landing gear lever when attempting an UP selection, but this lever moved without restriction.

The LIFT DUMP FAIL and ANTI SKID FAIL both resulted from discrepancies in the indications between the left and right WOW switches: following the takeoff the right WOW switch continued to show the aircraft ON GND and the left switch correctly showed the aircraft IN AIR. Both systems contained monitors for this disagree and, after the pre-requisite delay time, provided the cockpit illumination. A further confirmation that the failures were related to the WOW switch was the discrepancy between the Hobbs meter reading, which is active when the right WOW is IN AIR, and the actual flying hours. With this information it was possible to confirm that the right WOW switch failed to indicate IN AIR following the takeoff from Humberside.

Tests later revealed the right WOW switch was electrically functioning correctly, placing suspicion on its fitting to the right main landing gear leg. Inspection of the switch installation had revealed that the support bracket for the WOW switch had fractured due to stress corrosion cracking. For the switch to indicate IN AIR, the target must compress the switch plunger. The progressive fracture of the bracket would have allowed flexure of the bracket. When the target, at takeoff, contacted the switch plunger the load imparted by the target transferred through the switch and to the bracket. But, instead of the bracket reacting these loads and operating the plunger the flexure allowed the switch to move upward, thus preventing operation of the microswitches. This would have led to a constant ON GND indication to the systems served by the right WOW switch.

The engineer who inspected the aircraft at Farnborough, following the flight from Humberside, indicated that the right WOW switch and support bracket were intact when he inspected them. However, the WOW switch had already failed to indicate IN AIR from Humberside. An explanation could be that the crack had not progressed enough to completely fracture the bracket, nor had it cracked enough to show movement during the physical examination. In addition, the bracket would have been very dirty and in a position of poor lighting, making it difficult for a detailed examination in these conditions. It can be concluded from this that the final fracture of the bracket was after the departure from Farnborough and may have occurred during the runway excursion and accident sequence at Blackbushe.

The switch installation was such that when the aircraft is airborne the switch is engaged and any failure to operate the plunger results in an ON GND indication, be it from a failed bracket or incorrect rigging. When the aircraft subsequently lands, all the WOW switches would show ON GND and would therefore be in the correct sense. Any BIT checks conducted at this point are being conducted with the switches in their expected state and will therefore pass, as was the case at Farnborough. The only way of isolating such a problem would be to jack the aircraft to simulate IN AIR. However, most of the tests can only be conducted with the aircraft on the ground, which makes for difficulty in troubleshooting a potential WOW switch failure.

The bracket had failed due to stress corrosion cracking, a mechanism which requires a corrosive environment to develop. This had been provided by the use of dissimilar metals, with the use of aluminium alloy for the support bracket and steel for the WOW switch mounting hardware. These had set up galvanic corrosion and provided the initial mechanism for the crack. The second mechanism for the cracking to develop is stress and this had been provided by the outer tang of the tang washer that had been forced against the edge of the tang support hole of the bracket. The reason for this had been due to the inner tang riding out of its key way and finding its way into the threads of the switch. This can only have occurred during the installation of the WOW switch and was most probably because of the tightening of the lower nut for rigging purposes without the concurrent adjustment of the upper nut. This rigging adjustment placed a torque on the switch body, which then caused it to rotate in relation to the fixed tang washer.

It was also discovered that both the left and right WOW switches had been installed with the lock washer between the lower nut and the bracket, and thus allowing its teeth to dig into the metal of the underside of the bracket. Again, this set up a similar galvanic corrosion mechanism, which could have contributed to the stress corrosion cracking. It is common engineering practice not to put a lock washer immediately against the structure due to the possibility of damage. The WOW switches had formed part of a modification to the lift dump system, and were installed based on the SB and kit drawings, however neither of these provided any clarity on how to install the switch with the attaching hardware in the kit.

Since this accident, Raytheon have issued SB 32-3678 which requires inspection of the WOW switch support brackets for cracking and provides information on the correct installation of the switch, placing the lock washer between the tang washer and the upper nut. Nevertheless, some features of the design are, in the opinion of the AAIB, unsatisfactory and could still lead to corrosion and or cracking and therefore the following recommendation is made:

Safety Recommendation 2004 - 95

It is recommended that Raytheon Aircraft Company review the design and installation of the weight-on-wheels switches and support hardware fitted to the Premier 1 aircraft, with a view to reducing the possibility of stress corrosion cracking.

Response to Recommendation 2004 - 95

Raytheon Aircraft Company has accepted this recommendation. In addition to the Mandatory Service Bulletin 32-3678 Raytheon Aircraft Company have revised the appropriate engineering drawings and production planning data to specify the correct assembly of the switches and attaching hardware. Finally, for new production aircraft (beginning at serial number RB-143), and spares, the switch attach bracket material has been changed to 4130 steel to improve corrosion protection.

Lift Dump Fail

The LIFT DUMP FAIL indication, on both the flight from Humberside and from Farnborough, was due to the right WOW switch failing to indicate IN AIR. This was confirmed by the read out of the memory of the SCU.

The system operation on N200PR was such that it was fully manual with the use of the lift dump handle to deploy all the spoilers which could be achieved during any phase of flight. With this modified system there was no reliance on the WOW switches for its operation, except for ground BIT testing. However, the modified system used the existing SCU with changes only being made externally to the unit, and with the manual handle serving as a method of fooling the control unit that the aircraft was on the ground, with engines at idle and the speedbrake switch in extend. However, the SCU still contained the monitor logic for a WOW disagree, and the inputs from the left and right WOW switches remained to facilitate BIT testing of the system. So, although the WOW switches are no longer required for the actual operation of the lift dump spoilers they will still provide a LIFT DUMP FAIL indication if there is a disagree for greater than six seconds. Therefore, following a

WOW switch failure the LIFT DUMP FAIL light will illuminate and render the system totally inoperative; although the system itself will still be operable. This logic seems flawed in that a serviceable system, essential for optimum braking, is inhibited for a failure unrelated to its operation. The following recommendation is therefore made:

Safety Recommendation 2004 - 96

It is recommended that Raytheon Aircraft Company review the logic of displaying a LIFT DUMP FAIL and inhibiting the system due to a weight-on-wheels switch disagree on the Premier 1 aircraft, and modify the system so that lift dump remains available.

Response to Recommendation 2004 - 96

Raytheon Aircraft Company has accepted this recommendation and has reviewed the lift dump system to evaluate weight-on-wheels (WOW) logic related to lift dump operation. The Spoiler Control Unit (SCU) controls all functions of the spoiler system: roll control, speed brakes, and lift dump. The SCU must successfully complete a Built-In-Test (BIT) prior to each flight in order to enable the various functions. The BIT sequence results in movement of the spoiler/lift dump panels, and thus must not occur whilst airborne. The WOW logic is required to inhibit BIT in flight. While it may be possible to modify the system design to eliminate annunciation of LIFT DUMP FAIL in the event of squat switch disagreement, such a modification would require changes to SCU hardware, software, and aircraft wiring. As noted below, Raytheon Aircraft Company is adding information to the Model 390 FAA Approved Airplane Flight Manual to clarify and expand landing performance information, including detailed procedures for use in the event of LIFT DUMP FAIL annunciation. Thus, Raytheon Aircraft Company considers that changes to SCU WOW logic may be appropriate as a product improvement at a later date.

Anti Skid Fail

The illumination of the 'ANTI SKID FAIL' light, during the flight from Humberside, can be directly attributed to the right WOW switch failing to indicate IN AIR following takeoff. The ASCU WOW monitor would have seen a mismatch between the left and right WOW switches, after takeoff, and 60 seconds later, provided a discrete indicating that discrepancy. The warning logic, defined by the aircraft manufacturer, interpreted the discrete and illuminated the ANTI SKID FAIL light in the cockpit.

However, when the ASCU diagnoses a WOW switch failure, it only removes the touchdown protection function, with all the remaining operations of the anti skid system still available. For the anti skid to become operational the system relies on either the wheel speed or the WOW switch indication. This means that even with a WOW switch disagree, once the wheel speed has reached 60 kt, the anti skid system will operate and provide the normal protection as long as the anti skid switch in the cockpit is still in the NORM position.

The pilot of the accident aircraft reported that he felt the anti skid operate at Farnborough, despite the ANTI SKID FAIL indication, so the anti skid switch is presumed to have been to be in NORM. At Blackbushe, the tyre markings, left by the accident aircraft, indicated normal operation of the anti skid, and the anti skid switch was found in NORM. Subsequent tests of the anti skid components did not reveal any faults with the system.

The checklist for an ANTI SKID FAIL requires the cockpit switch to be moved to OFF, which would remove the anti skid protection, although full braking would still have been available. With a WOW failure, the logic of the aircraft is to illuminate the ANTI SKID FAIL despite the fact that the anti skid system is still functional, with the exception of touchdown protection. If the checklist is followed then a perfectly serviceable system is switched off. Other aircraft types, fitted with a similar anti skid system from the same manufacturer, do not indicate an ANTI SKID FAIL to the crew in the event of a WOW switch failure but store this failure information in a maintenance memory instead.

The anti skid system does not contain any memory, which means it is not possible to carry out any post flight analysis or troubleshooting following a failure. The only action is to carry out a BIT check, which shows the serviceability of the system at the time it is tested. With a WOW switch failing to indicate IN AIR, then a ground BIT test will always pass, as the switches would now be in the correct sense (ON GND). The only way to find this fault would be to jack the aircraft to simulate an aircraft in the air. This makes it difficult to isolate the WOW switches as a cause of the ANTI SKID FAIL, unless there are other indicators such as a maintenance memory or other system faults that can be cross related.

Safety Recommendation 2004 - 97

It is recommended that Raytheon Aircraft Company review the logic of displaying ANTI SKID FAIL for a weight-on-wheels switch disagree on the Premier 1 aircraft, when the system is otherwise still operational.

Response to recommendation 2004 - 97

Raytheon Aircraft Company has accepted this recommendation and has reviewed the anti skid system to evaluate WOW logic related to anti skid operation. While it is possible to modify the system design to eliminate annunciation of ANTI SKID FAIL in the event of squat switch disagreement, such a modification would require changes to anti skid system hardware and software. As noted below, Raytheon Aircraft Company is adding information to the Model 390 FAA Approved Airplane Flight Manual to clarify and expand upon the anti-skid system, including detailed procedures for use in the event of ANTI SKID FAIL annunciation. Thus, Raytheon Aircraft Company considers that changes to the system related to WOW logic may be appropriate as a product improvement at a later date.

Operational issues

After taking off from Humberside the pilot was presented with a series of indications that created a high cockpit workload and necessitated a diversion and landing with two critical systems apparently unserviceable. The pilot referred to the LIFT DUMP FAIL abbreviated checklist, which simply advised that the landing distance would be increased by 53%. With 1,800 metres of LDA Farnborough had sufficient runway for landing with a failure of the lift dump system and had some operational advantages. However, the large increase in LDR when landing with anti skid inoperative in addition to the increased LDR required for the lift dump failure would have exceeded the LDA at Farnborough. The pilot believes that he also referred to the ANTI SKID FAILURE checklist, but given the checklist requirement to turn the anti skid switch OFF and to land with Flap UP or Flap 10 it seems possible that these items may have been missed in the high workload environment. Fortunately, as outlined above, the ANTI SKID FAIL indication was indicative of a touchdown protection failure only and the anti skid system was in fact serviceable, but this was not known to the pilot before he landed.

The landing at Farnborough was largely uneventful and to some extent would have conditioned the pilot's attitude and decision making for the subsequent flight to Blackbushe. The pilot had been cleared to land short of the displaced threshold on Runway 24 at Farnborough and after touchdown the braking appeared effective, despite the fact that maximum braking was not used and, confusingly for the pilot, the anti skid system appeared to work. To a certain extent the latter would have added to the pilot's low confidence level in the authenticity of the aircraft's warning systems. The LDA was more than sufficient for the lift dump failure, and the aircraft cleared the runway with adequate landing distance remaining.

The checklists for the technical problems experienced during the flight from Humberside left the pilot short of some critical information. There was no checklist to cover the landing gear failing to retract after a normal UP selection. The LIFT DUMP FAILURE (LIFT DUMP FAIL ANNUNCIATOR ILLUMINATED) abnormal checklist gave no advice on braking technique required nor did it provide the very helpful **Warning** about braking effectiveness found in the emergency checklist for LIFT DUMP FAILS TO EXTEND (LIFT DUMP WARNING TONE

SOUNDS). There was no advice on how to apply performance decrements for multiple failures and the ANTI SKID FAILURE (ANTI SKID FAIL ANNUNCIATOR ILLUMINATED) in the abbreviated checklist did not contain the **Caution** that landings with flaps 20 or DN were prohibited. On the other hand the pilot did not use all the checklist information that was available, and there appears to have been an element of good fortune in the uneventful landing at Farnborough.

The engineer's suggestion that the aircraft be taken to Blackbushe for further technical investigation was sensible given the aircraft's history. The pilot checked the LDR and calculated that there was just sufficient LDA with the lift dump system inoperative and, given his recent experience of landing at Farnborough, it is perhaps not surprising that he decided that a successful landing was possible. However, in retrospect it appears that the pilot had less than a full understanding of the actions required to achieve the published landing performance and certainly he was not aware of the braking effectiveness profile that was to be expected. Although the AFM contained some of this information, there were deficiencies in the way that it was presented.

Witness evidence together with recorded data from the EGPWS indicates that when landing at Blackbushe the aircraft touched down at about the correct point on the runway and there is no evidence to counter the pilot's perception that the aircraft touched down at the correct speed. Apart from the WOW faults outlined above no other fault was found with the aircraft systems. Using this evidence, performance calculations, supported by the AAIB flight test, indicate that the aircraft should have been able to stop in the available distance at Blackbushe provided the correct techniques had been applied. In the event, the pilot did not apply maximum braking immediately after touchdown and released and reapplied the brakes in an attempt to achieve perceived braking. Both these actions would have reduced the braking effectiveness and the deceleration would have been significantly less than that achievable had the correct braking technique been applied. It is also possible that the initial deceleration achieved at Blackbushe was lower than that at Farnborough as a result of the lower friction of the runway and the significantly reduced aircraft weight for the landing at Blackbushe. All of these factors would have added to the pilot's perception that the brakes were not functioning.

In the circumstances the pilot's decision to go-around was understandable and it appears likely that if he had kept the throttles at full power for just a fraction of a second longer, a successful go-around might have been achieved. However, once the decision to abort the go-around attempt had been made the runway overrun became inevitable.

Safety actions

This accident, together with similar accidents to the same type, have revealed a number of weaknesses in both pilot awareness of the aircraft's landing performance and the AFM, the abbreviated checklist and the presentation of performance data. The manufacturer has published a very useful Safety Communique on landing performance and has offered all current owners of the type a Supplemental Familiarization programme to help increase awareness of the issues. In addition the manufacturer has made changes to its initial flight training programme. The AFM issues remain and the following recommendation is therefore made:

Safety Recommendation 2004 - 98

It is recommended that Raytheon Aircraft Company should carry out the following amendments to the Airplane Flight Manual for the Premier 1 aircraft:

1. Revise the Lift Dump Failure (Lift Dump Annunciator Illuminated) abnormal checklist to include recommendations on required braking technique and to include the **Warning** of braking efficiency published as part of the Lift Dump Fails to Extend (Lift Dump Warning Tone Sounds) emergency checklist.

2. Review all Airplane Flight Manual and abbreviated checklists to ensure that flight critical items included in **Warnings** and **Cautions** in the Airplane Flight Manual are included in the appropriate abbreviated checklists.

3. Expand the Performance section of the Airplane Flight Manual to include advice and, where appropriate, data for multiple system failures.

4. Amend, where appropriate, performance charts to include all associated conditions on which the published performance is based.

Response to Recommendation 2004 - 98

Raytheon Aircraft Company has accepted this recommendation and is finalizing an extensive revision to the Model 390 Pilot's Operating Manual, FAA Approved Airplane Flight Manual, and FAA Approved Abbreviated Pilot Checklist. The revisions include the following:

> Expanded information about lift dump and anti skid systems. The information includes details of operation and procedures to be followed in event of LIFT DUMP FAIL and ANTI SKID FAIL annunciation, both alone and in combination. Procedures for identification of, and response to, WOW switch failure have been added. Detailed information about braking technique and performance is included for these conditions.

Consistent information between the Airplane Flight Manual and abbreviated checklist regarding failure annunciations and related procedures.

Guidance for application of performance factors in response to failure annunciations.

Clarification and consistent presentation of the conditions under which performance data was derived. Detailed information about the effects of variations in those conditions has been included.

Addition of wet and contaminated runway landing performance data. The data will be presented as supplementary, non-approved data.

Finally, the performance charts used in this aircraft's Airplane Flight Manual are widely used but nevertheless are of a scale and complexity such that mistakes can easily be made, particularly during single-pilot operations. In this accident, the pilot interpreted the graphs correctly, but the potential for human error in the use of these graphs is significant and could be the cause of future incidents and accidents. The following Safety Recommendation is therefore made:

Safety Recommendation 2004 - 99

It is recommended that Raytheon Aircraft Company review the presentation of performance data in the Airplane Flight Manual for the Premier 1 aircraft to render it less susceptible to errors in interpretation.

Response to Recommendation 2004 - 99

Raytheon Aircraft Company has accepted this recommendation. The Airplane Flight Manual and abbreviated checklist performance data is to be presented in tabular format, and will include corrections for runway gradient and wind component. The Pilot's Operating manual, Airplane Flight Manual and abbreviated checklist revisions are presently in process and it is expected that the revisions will be published at the end of 2004.

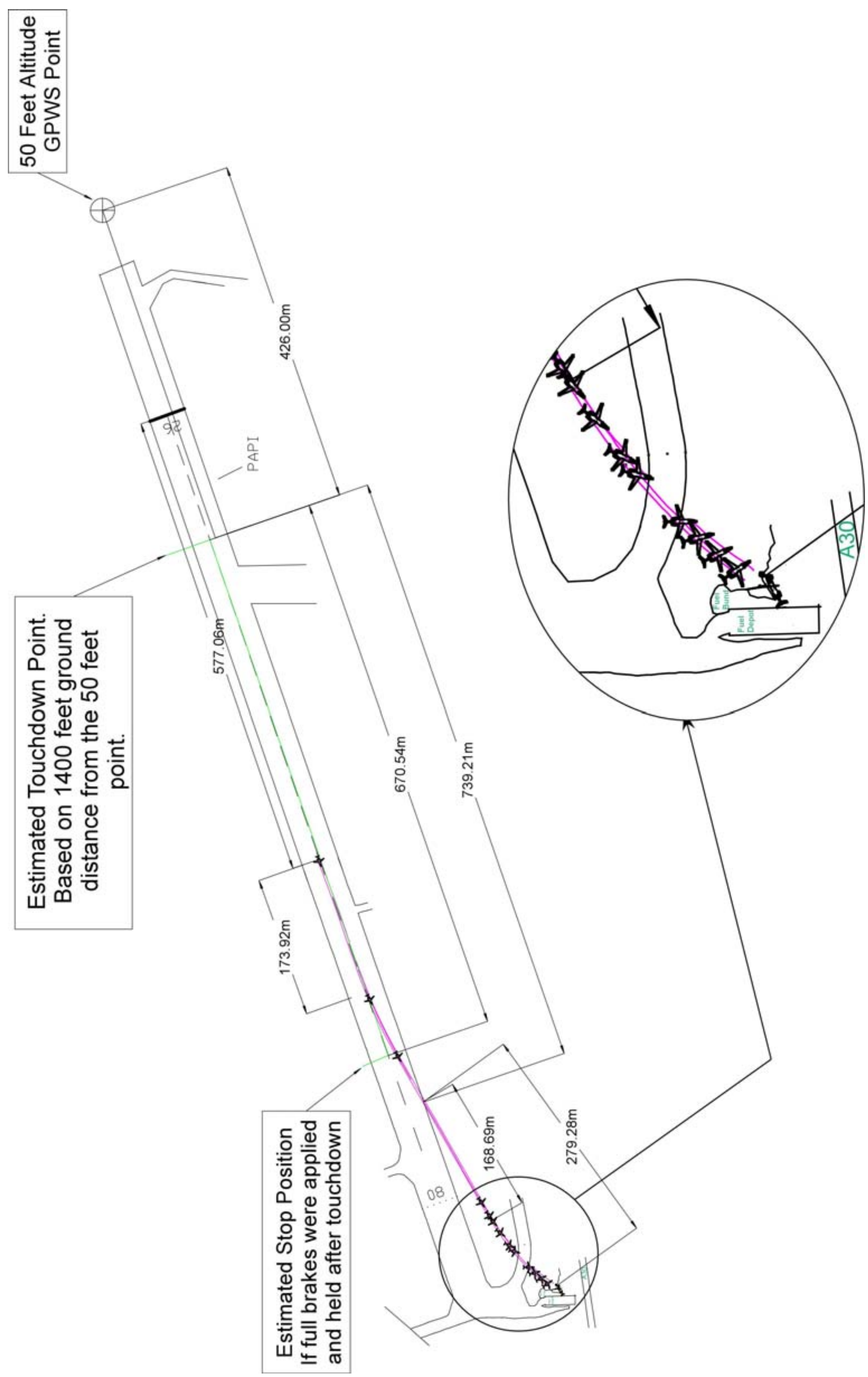


Figure 1 - Accident Sequence

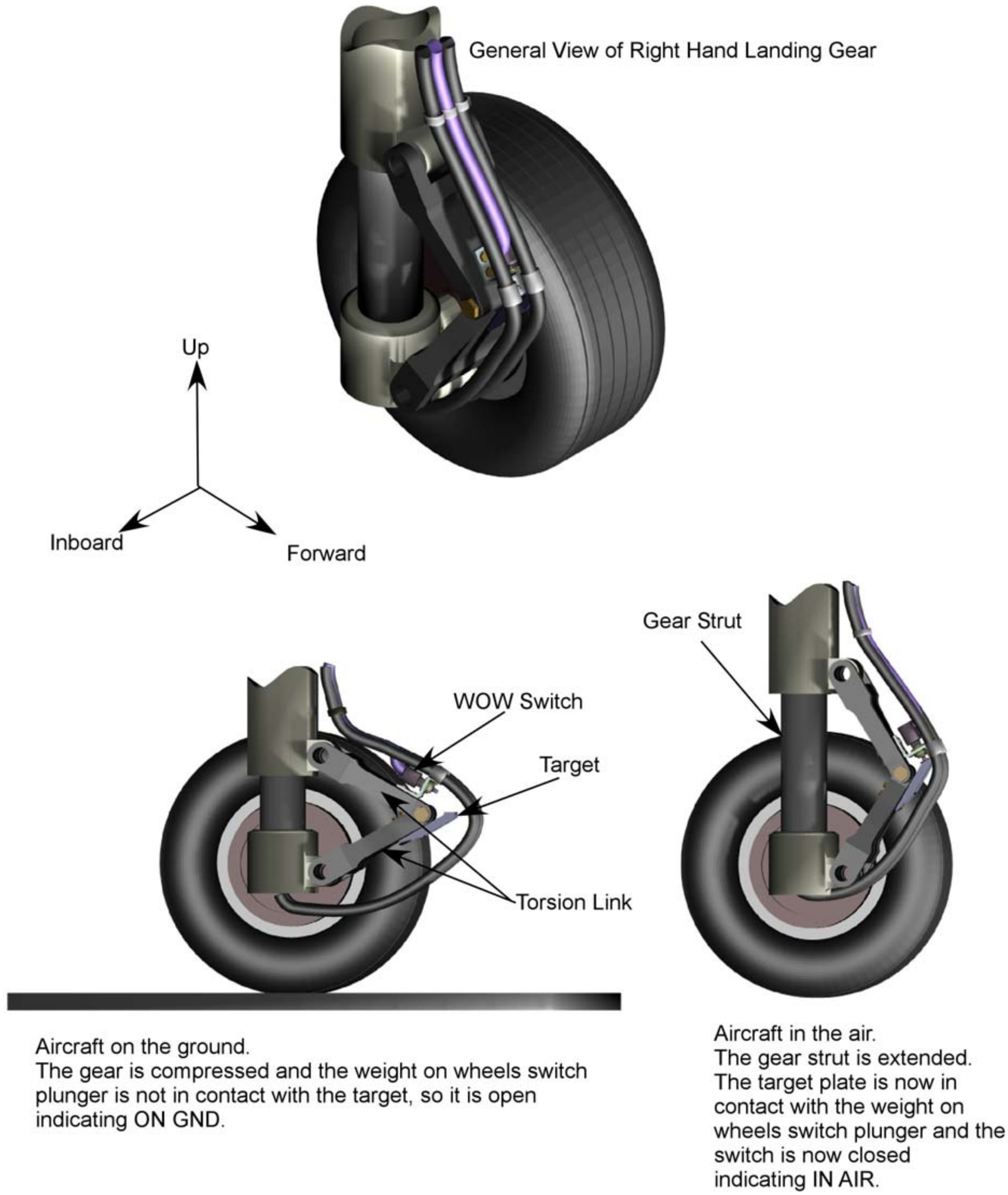
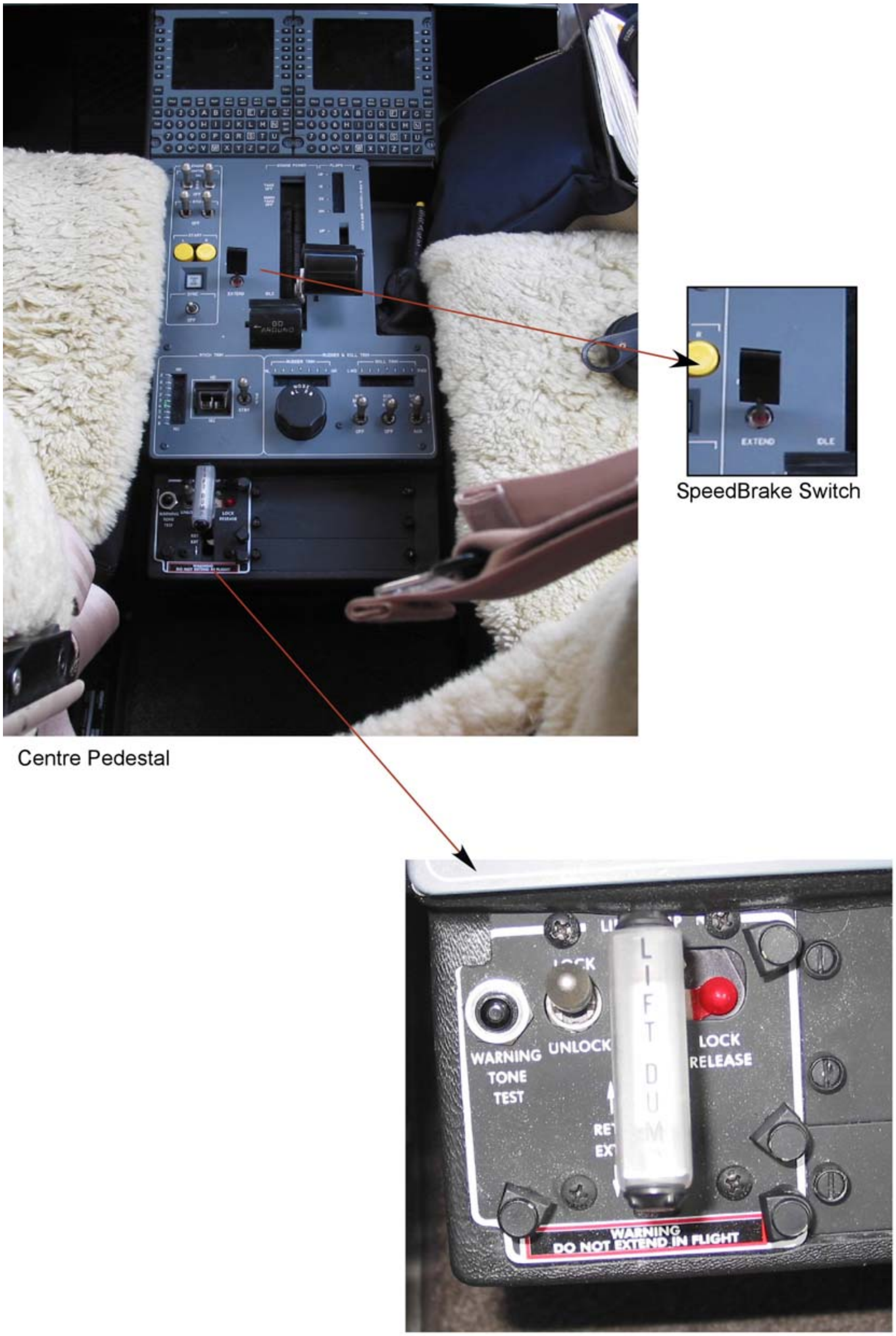


Figure 2 – WOW Switch installation.



SpeedBrake Switch

Centre Pedestal

Post Modification Lift Dump Handle as fitted to N200PR

Figure 3 - Lift Dump and Speedbrake components

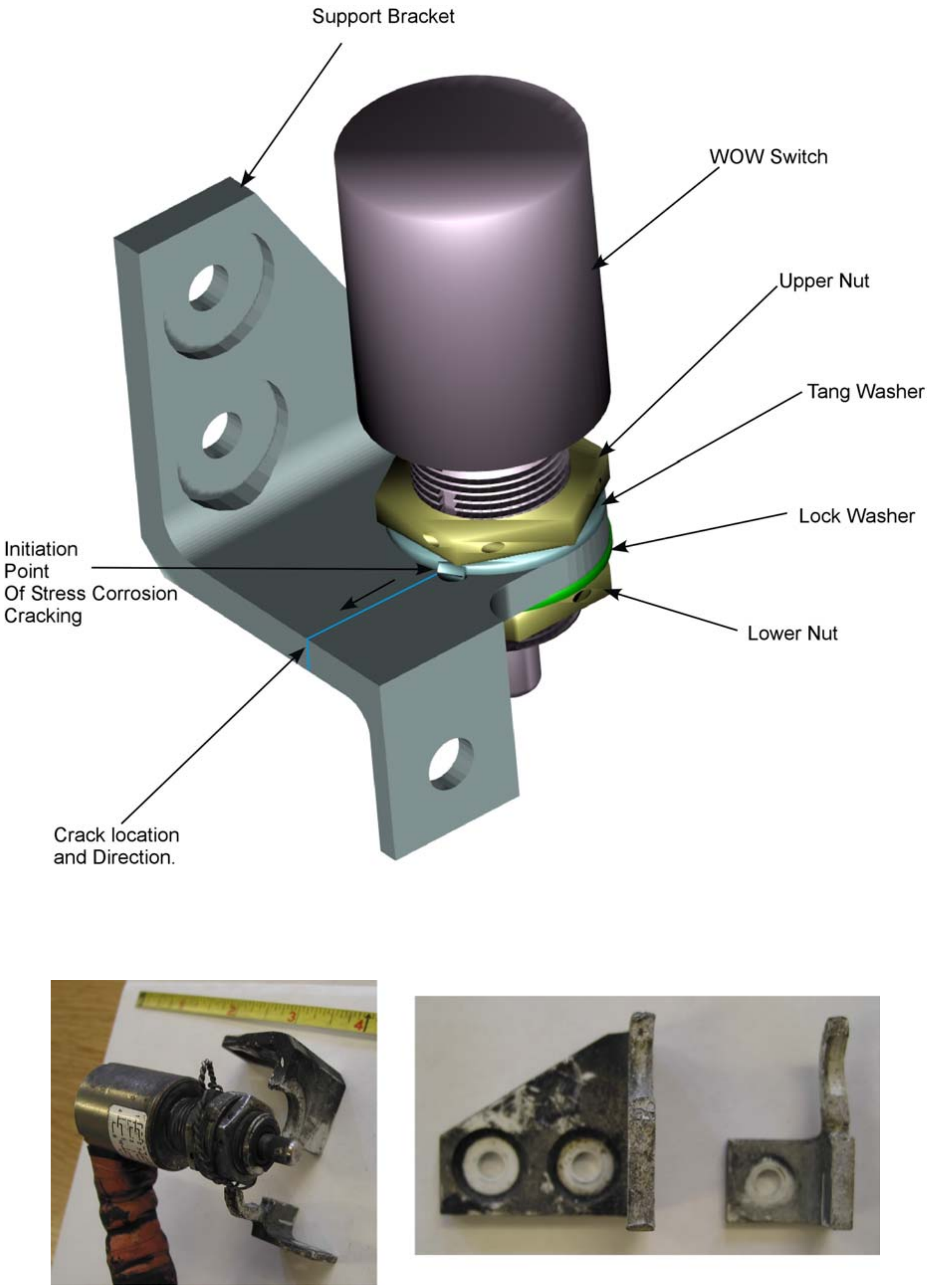


Figure 4 – WOW switch bracket.

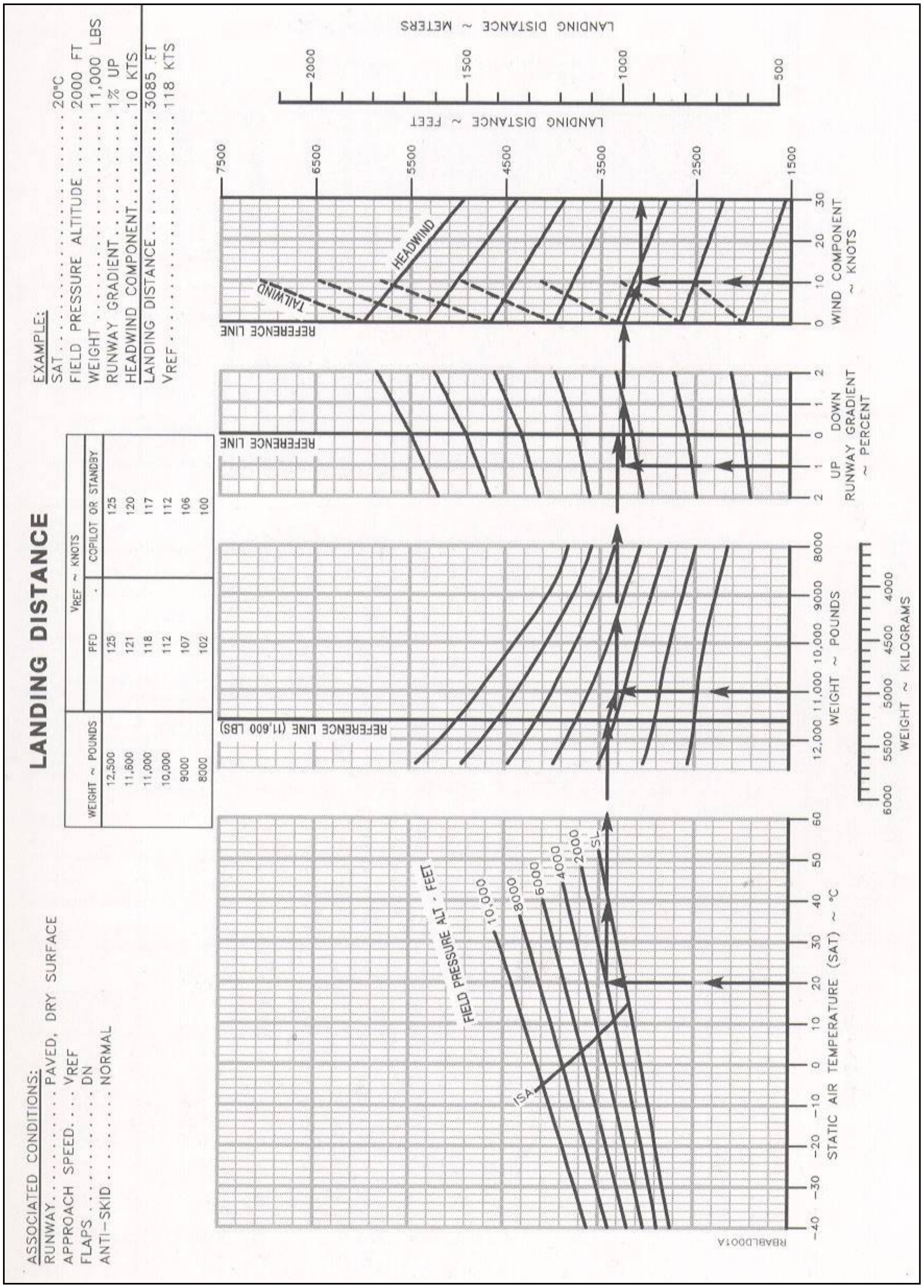


Figure 5 - Normal Landing Performance Charts

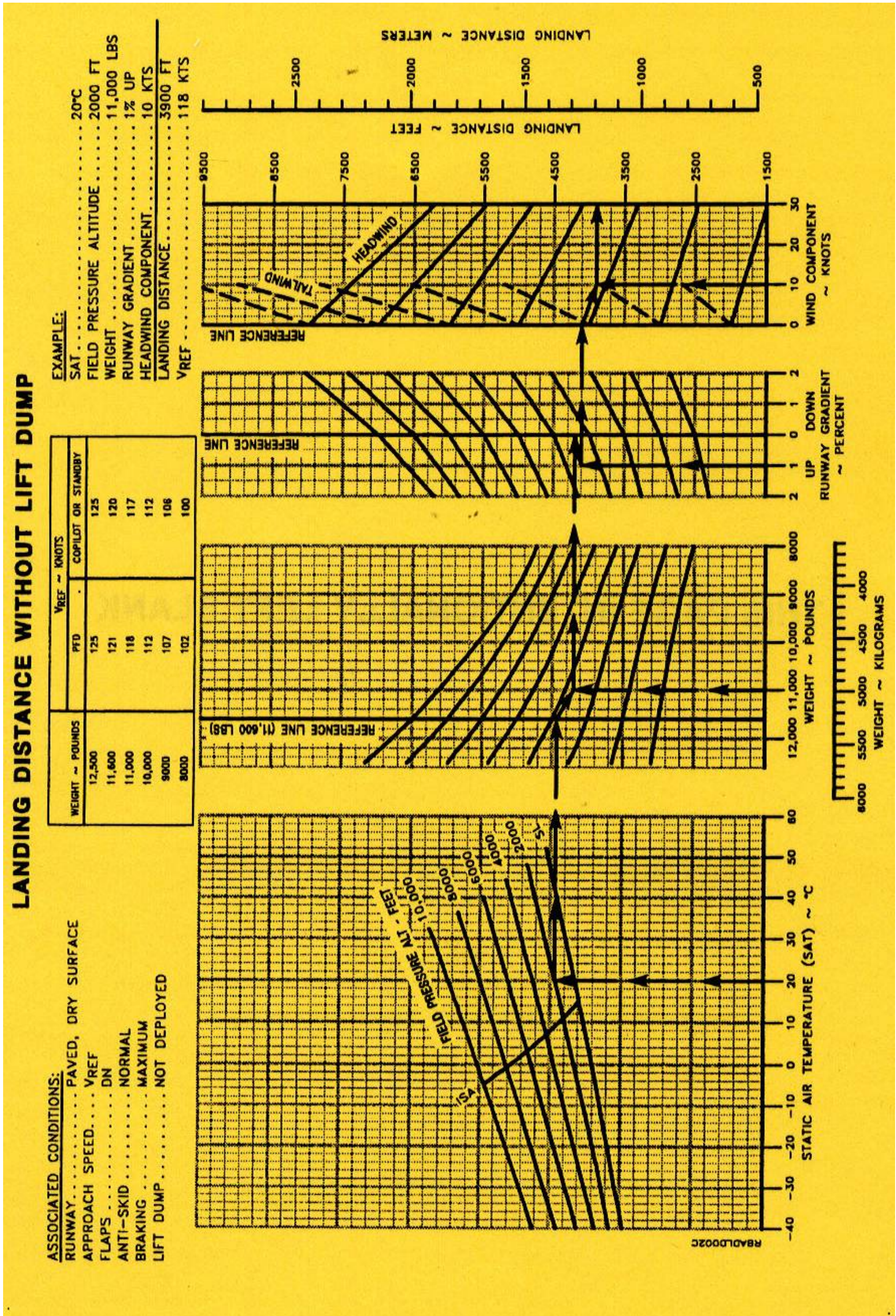


Figure 6 - FAA AD imposed Landing Performance Chart without Lift Dump

APPENDIX A – SCU FAULT MEMORY DOWNLOAD.

The fault memory download of the SCU revealed the following, with the latest fault recorded first and spaces inserted for clarity.

Fault Code	Meaning	Possible reason for fault code
2	Monitor CCA 1	Power loss
1	Control CCA	Power loss
V	Aircraft Power	Power Disconnect
Q	Right throttle at power sw	Wiring being pulled out during accident
O	Right throttle at idle sw	Wiring being pulled out during accident
R	Left throttle at power sw	Wiring being pulled out during accident
Q	Right throttle at power sw	Wiring being pulled out during accident
P	Left throttle at idle sw	Wiring being pulled out during accident
O	Right throttle at idle sw	Wiring being pulled out during accident
N	Left WOW switch	Unknown
M	Right WOW switch	Unknown
J	Right pneumatic out of limits.	Wing impact with fuel bund
G	Right pull down/hold down actuator	Wing impact with fuel bund
1	Control CCA	Unknown
N	Left WOW switch	WOW discrepancy out of Farnborough
M	Right WOW switch	WOW discrepancy out of Farnborough
		BIT test reset in between flights
N	Left WOW switch	WOW discrepancy out of Humberside
M	Right WOW switch	WOW discrepancy out of Humberside
V	Aircraft Power	Test
V	Aircraft Power	Test
U	Left i/b panel stow sw	Unknown
-	No more data	Data cleared at maintenance
-	No more data	
-	No more data	